LOW SPEED VEHICLES AND MICROMOBILITY DEVICES: OCCUPATIONAL USES, RISKS AND CONTROLS

White Paper

L.A. Weaver Co., Inc.

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308 E. Jones St. Raleigh, NC 27601
aweaver1@bellsouth.net 919.621.5899 laweaverco.com

Low Speed Vehicles and Micromobility Devices

Key Takeaways

- Low speed vehicles, including but not limited to golf carts, UTVs and ATVs, are primarily being used occupationally for maintenance purposes and equipment transportation especially where automobiles have restricted access.
- Micromobility devices, including but not limited to electric scooters and electric bikes (also known as and referred to in all instances here as e-scooters and e-bikes), provide a means of income for delivery workers, device chargers (juicers) and competitive racers.
- Low speed vehicles and micromobility devices are by definition mutually exclusive categories. Both are similarly used in occupational environments.
- The invention of the bicycle in 1817 and the motorized bicycle in 1902 led to popularized forms of wheel transport that have aided in the transportation of goods and services, such as cargo and messenger bicycles that still operate and have proliferated as costs for transportation mechanisms have increased.
- Regulations in many countries concerning safe operation of low speed vehicles and micromobility devices include requirements for speed limits, insurance, licensing and registration, and physical features including, but not limited to, windshields, lamps, reflectors and brakes.
- The most common cause of injury or fatality in low speed vehicle related incidents since 2000 has resulted from falls from the vehicle. For micromobility devices, particularly e-bikes and e-scooters the most common cause of injury is head and upper extremity injuries, such as concussions, particularly for e-bikes and e-scooters.
- Technological advancements in both low speed vehicle and micromobility designs allow for more safety features such as LED headlights, seat belt systems, back up warning alarms, GPS navigation, and user adjustable horns

Introduction

This paper will address the classfications, regulations, occupational uses, injuries and safety measures specific to some micromobility devices, specifically e-scooters and e-bikes, and some low speed vehicles (hereinafter referred to as LSVs), namely golf carts, ATVs (all-terrain vehicles) and UTVs (utility task vehicles). The aim for this paper is to provide consumers and industry safety professionals with the proper resources and recommendations to ensure safety of their workers should they elect to utilize micromobility devices and/or low speed vehicles in select work environments. As the LSV and micromobility sectors grow, they create more risks for the occupational safety and health of individuals nationwide. Hoverboards, while falling under the category of micromobility devices, will not be discussed in detail as they are susceptible to major fire safety hazards and also do not provide a safe means of transportation.

Federal Motor Vehicle Safety Standard (FMVSS) No. 500 (49 CFR 571.500), "Low-speed vehicles," defines an LSV as "a 4-wheeled motor vehicle, other than a truck, whose

speed attainable in 1.6 km (1 mile) is more than 32 kph (20 mph) and not more than 40 kph (25 mph) on a paved level surface" (Elias, 1998). Examples of low speed vehicles include golf carts and all terrain vehicles (ATVs). OSHA distinguishes between UTVs and ATVs, stating "an ATV is an off-road, single-rider vehicle intended for transport over rough terrain… A UTV is also intended for use over rough terrain, though this vehicle is sometimes known as a side-by-side because two people can sit in the cab next to each other. Both can be used to haul items, but a UTV features a truck-like bed specifically for this purpose." (Occupational Safety & Health Administration, 2024). For variations based on speed limits and vehicle weights in select other countries, see Table 1.

Table 1

Definitions of Low Speed Vehicles in Other Countries

Country	Definition	Speed Limit	Weight
Canada	● Are designed for use primarily on streets and roads where access and the use of other classes of vehicles are controlled by law or agreement ● Travel on four wheels ● Are powered by an electric powertrain ● Do not use fuel as an on-board source of energy	≤40 kph (~25 mph)	≤ 1361 kg
China	A passenger or freight electric vehicle driven by motor and taking lead-acid cell or lithium battery as driving power,	≤70 kph (~ 43 mph)	N/A
Germany	An electrical vehicle not allowed on highways (Autobahn), but may use other roads, including rural roads and urban streets	≤45 kph (~ 28 mph)	≤400 kg
Japan	Small-scale transportation services that utilize electric vehicles running on public roads. Also known as Green Slow Mobility (GSM)	≤32 kph (20 mph)	N/A

The Federal Highway Administration broadly defines micromobility devices as "any small, low-speed, human or electric-powered transportation device, including bicycles, scooters,

electric-assist bicycles, electric scooters (e-scooters), and other small, lightweight, wheeled conveyances" (Price et al., 2021). The Society of Automotive Engineers (SAE) expands on this definition in SAE J 3194-2019 *Taxonomy And Classification Of Powered Micromobility Vehicles*, describing micromobility devices as "A category of powered vehicles that have a curb weight of less than or equal to 500 lbs (227 kg) and a top speed of 30 mph (48 kph) or less" (Society of Automotive Engineers, 2019).

Micromobility devices, particularly e-bikes and e-scooters, have become a popular alternative mode of transportation for children and adults, both competitively and recreationally. These devices are capable of reaching faster speeds than non-motorized forms of transportation such as bicycles, skateboards and push scooters. Chang et al. found that "Micromobility is used for both utilitarian and recreational purposes. In Austin, 35 percent of a survey's respondents ranked work and school commutes as their most frequent purpose for using dockless e-scooters and e-bikes. In Portland, 20 percent of a survey's respondents ranked work and school commutes as the top purpose of e-scooter sharing trips. In a survey conducted in San Francisco, Lime found that the primary trip purpose for 55 percent of their e-scooter riders was for work and school commutes" (2019). Some individuals use the devices for food and cargo delivery jobs and forest park maintenance. Cargo e-tricycles are also a popular choice in several countries for delivery of packages and food (Liu et al., 2021). Operators of LSVs and micromobility devices are exposed to safety risks from inadequate transportation regulations and safety features, high risk of injury and under-developed city infrastructures, including designated travel lanes and docking/charging stations.

History of Bicycles and Their Motorization

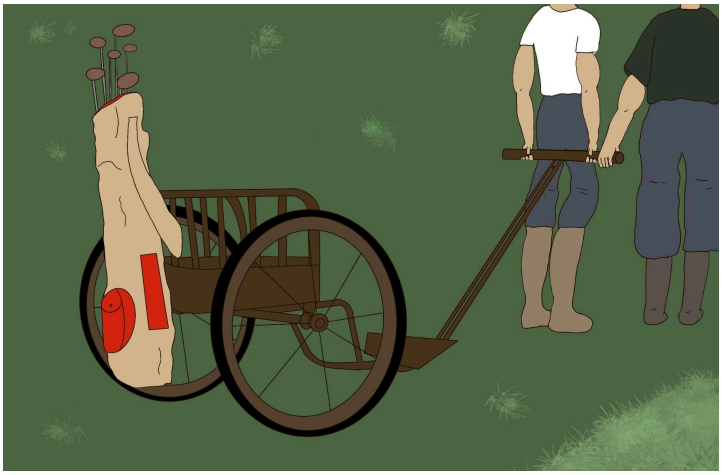
The first patenting of the bicycle is credited to Karl von Drais in 1817 after a bad period of harvest created a need for a horseless mode of transportation to enable the rider to transport goods and other materials. This invention was known at the time as the "Draisine" or "Velocipede" and consisted of a wood frame with two wheels in line with each other and a leather saddle nailed to the frame. It was operated by a rider pushing against the ground with both their feet to propel themselves forward (Malizia & Blocken, 2020). Throughout the 1800s, various adjustments were made to this design in order to improve the speed and user comfort. Inventors around the world experimented with wheel sizes and materials, mechanical controls, tangent spokes, and rear wheel chain drives which ultimately led to the design of today's bicycles (Asokan et al., 2017).

After the 1880s, inventors began to experiment with a motorized version of bicycle transportation. In 1902, a one cylinder gasoline engine with a tomato can for a carburetor was equipped by Glenn Curtiss of G. H. Curtiss Manufacturing company to a bicycle's frame to achieve motorization (Audrain, 2023). Improvements of the motorcycle's engine began after its invention and in 1907, Curtiss set a land speed record at Ormond Beach, Florida. It began with a two-man push to start the bicycle; he then completed the mile-long timed run at 136.36 mph

which was faster than any automobile had traveled at that point in time (Rinek, 1994). These various design advancements led to the development of competitive motorsports as an occupation for athletes, trainers, and maintenance personnel. The invention of the bicycle also led to the development of other low speed vehicles such as the golf cart. An avid golfer but also an arthritic person, Lyman Beecher is widely credited with creating a rickshaw-type cart in 1932. It was originally unpowered and required two caddies to pull the cart with the player on it. This occupational task was not well-appreciated by the caddies who were each paid $1.00 per round for pulling the cart and soon after it was replaced by mechanical apparatuses including batteries and fossil fuels (Pace, 2021).

Figure 1

Drawing of first golf cart created by Lyman Beecher



This design also utilized bicycle wheels of the 1900s in order to travel over the hilly grounds of the golf courses (Cart Barn, 2023). After its reported 1935 debut at the Biltmore Forest Country Club in Asheville, North Carolina, Beecher added two additional wheels and six car batteries to create an independently operated golf cart. However, it was only able to propel itself for short distances (Cabral, 2023). This early human-powered model can be seen in Figure 1. Electric golf carts were invented in the same decade as the rickshaw style golf cart, but due to high costs and the inability to travel great distances, most golfers continued to walk the course. In the 1950s a gasoline-powered golf cart was marketed by R.J. Jackson, but this cart was flawed by being noisy and producing smoke on the golf course which resulted in it being banned (Pace, 2021). As inventors found ways to reduce the smoke and noise produced by these low-speed vehicles, the modern golf cart evolved and can now be used legally on many roadways if regulatory compliant with local and national rules or regulations.

Occupational Uses for LSVs and Micromobility Devices

Cargo/messenger bicycles have been existent since the late 1800s when motorized forms of transportation were still new concepts. “Throughout the late 19th and early 20th centuries,

telegraph companies employed persons (primarily young men and boys) to deliver telegrams by bike. UPS made all of its deliveries on foot or by bicycle until it acquired its first Model T Ford in 1913… The period between 1980 and 2007 is largely considered the heyday of the messenger industry" (Daddio, 2020). In population-dense cities such as New York City, operators of cargo/messenger bicycles earn their wages by completing deliveries for their clients. Cargo bikes can be preferred over delivery vans because they "seldom obstruct traffic lanes, cycle paths or crosswalks when idle. And they don't worsen street congestion by circling the block in search of a place to unload, which can consume up to 28% of van drivers' time" (Zipper, 2021).

The New York City Department of Transportation implemented a new cargo program in 2019, allowing pedal-assisted cargo cycles to be up to 48 inches wide and have up to four wheels in order to reduce traffic and emissions. This 2019 program launched with 3 delivery firms: DHL, Amazon, and UPS as participants with 100 e-bikes and in 2021 the pilot grew to 6 participants and 350 micromobility devices. Between May of 2020 and January 2021, cargo bicycle deliveries increased 109% with the program expanding into Brooklyn in June 2020 (New York City Department of Transportation, 2021) Data collected in 2022 found "cargo bikes made more than 130,000 trips delivering over 5 million packages, resulting in the reduction of over 650,000 metric tons of CO_2 emissions, and demonstrating their effectiveness as a last-mile delivery mode" (New York City Department of Transportation, 2023). The New York City Department of Transportation Commissioner noted "Just two cargo bikes can replace one box truck, increasing safety and reducing CO_2 emissions by 14 tons per year — equivalent to 30,872 passenger car miles traveled" (New York City Department of Transportation, 2023).

Companies in the gig economy such as DoorDash, UberEats, and Postmates also employ these individuals to complete food deliveries using their own car, scooter or bicycle, requiring that they have a valid driver's license and social security number. In lieu of a fixed salary, gig economy employees "are paid per gig or a 'piece rate' and service providers are linked to service users via an app" (Christie & Ward, 2019). Following the COVID-19 pandemic, use of public transportation in the U.S. decreased and many individuals began having food delivered directly to their homes, thus sparking a surge of e-bikes and e-scooters in the gig economy. This surge has been observed internationally as well. A 2022 study researching bicycle food delivery riders (BFDRs) in China, Great Britain and Australia found that in China, there were 7 million e-bike riders registered on the major delivery platforms. From 3,401 observations of riders across different days of the week and times of the day in Australia, the majority (66%) were food delivery riders (Oviedo-Trespalacios et al., 2022). For companies such as Lime or Bird that mainly sell e-scooters, employees are tasked with maintenance operations for the devices rather than using them for delivery. Customers utilize these services via an application downloaded on their mobile device which allows them to locate a scooter, then pay to unlock it and use it for transportation.

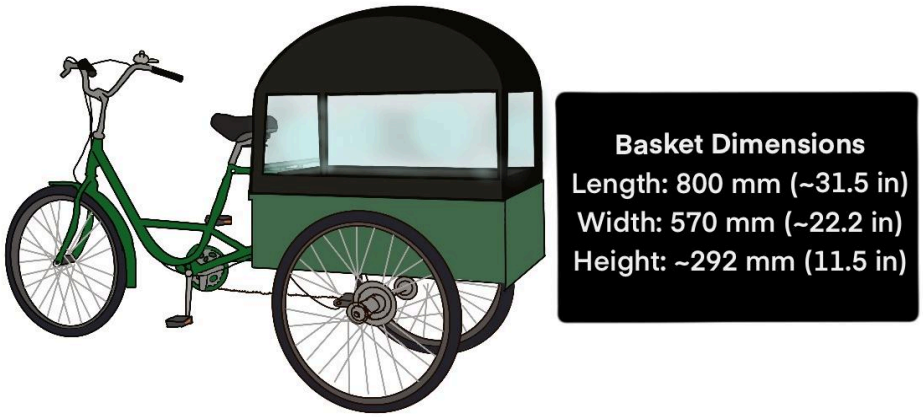
The National Park Service also utilizes micromobility devices for job duties by equipping e-bikes with cameras, computer tablets, and accelerometers (vibration measurement) to assess the roughness of the park trails. This allows park rangers to “cover longer distances and populate a geodatabase with 360-degree panoramic images, which are captured at one-second intervals, along with GPS coordinates' ' (Chiarenza et al., 2022). E-bikes are also used by personnel from the Federal Lands Highway (FLH) and the Olympic National Forest to evaluate park conditions, collect geospatial data and access areas unreachable by motor vehicles for maintenance. To ensure user safety, Seattle Parks and Recreation partnered with the Seattle Department of Transportation to establish an e-bike policy for their multi-use trails which included installing safety signs and a speed limit of 15 mph for micromobility devices (Chiarenza et al., 2022). Park rangers deemed these methods to be more efficient as they do not inhibit park visitors from their paths nor require additional parking space.

ATVs and utility carts can be utilized for park duties as well (Chiarenza et al., 2022). Farmers are using ATVs for agriculture related tasks such as pulling trailers/heavy loads, gathering livestock, applying pesticides and fertilizers, and maintaining fences. Firefighters may use either ATVs or UTVs for emergency response extraction, wildfire management, and transporting EMS personnel. Occupational uses for UTVs include carrying construction equipment, traversing for oil and gas production, and farming and ranching; they are also used in military operations (SafetySkills, 2024; Occupational Safety and Health Administration, 2024). Elsewhere, golf and utility carts are used for transportation on college campuses, large warehouses and airports. Occupational use in large warehouses and parks is mostly for utility purposes such as moving materials and equipment needed (Allen, 2015).

Countries including Germany and China are now utilizing e-tricycles for package delivery. Germany began a pilot project in 2019 to analyze how changing to this mode of transportation will affect the flow of traffic and length of time it takes for a parcel to be delivered. Currently their pilot program is only for packages between 300-350 kg (661-771.6 lbs) in weight (Liu & Bogdanski, 2021). Without a pilot study, China fully implemented cargo e-tricycle devices into their delivery services. These e-tricycles in China have a speed limit of 15 mph and have a package weight limit between 300-350 kg (661-771.6 lbs). China also has a category for cargo delivery couriers designated as heavy-load capacity tricycles which can load up to 600 kg (1322.8 lbs) and have a speed limit of 35 mph or less. Currently the only Chinese regulations for these cargo e-tricycle couriers are in regards to speed and weight limits, areas of operation, and driver’s license requirements. Other countries are examining the operations of these micromobility devices to determine what safety standards should be implemented (Liu & Bogdanski, 2021).

Figure 2

Cargo Tricycle with Typical Basket Dimensions



E-tricycles are also used for passenger transport, as seen with specific types of the device such as pedicabs and rickshaws which are common in countries such as China, India, Sweden, and Germany (Campisi et al., 2022). A popular option of e-tricycle passenger transport in the United States includes an attached basket designed to seat 4-6 children while an adult pedals from the bicycle seat (Bunch Bike, 2024). The basket is equipped with seats and seatbelts for the seated occupants. According to a 1965 report from the U.S. Federal Aviation Agency, the mean vertical sitting center of gravity for children 5 to 18 years old ranges from 8 inches to 9.5 inches, with a standard deviation of 0.52 inches (Searingen & Young, 1965). To ensure that the 99th percentile (plus three standard deviations from the average) of this population is adequately protected from the risk of falling out when seated, the baskets of e-tricycles designed to carry children should be at least 11.06 inches high.

Regulations Around the World for Low Speed Vehicles and Micromobilty Devices

Golf carts, while falling under the classification of an LSV, are also known around the world as neighborhood electric vehicles (NEV) and are classified as M vehicles in Europe (Transport Policy, 2018). The National Highway Traffic Safety Administration allows these low speed vehicles on roadways in the United States where the posted speed limit is no more than 35 miles per hour. Additionally, all operators are required to have a valid driver's license, and the vehicle must be registered and licensed in the same manner as a passenger vehicle. LSVs are also subject to the same insurance requirements as regular motor vehicles such as cars (United States Department of Energy, 2006). While these are the federal regulations, many states have additional requirements before a golf cart can be declared street legal. These requirements vary state-to- state, but the most common include:

- head/tail lamps
- stop lamps
- front/side/rear reflectors
- front/rear turn signals
- fenders
- a safety glazed windshield
- seat belts
- windshield wipers

- a mirror
- a horn
- safety belts
- manufacturer's identification number

Ohio also has a required vehicle inspection golf carts must pass before driving on roads (Mitran et al., 2020).

In the late 2010s, many electric bicycle and scooter companies started to deploy their devices in different cities across the U.S. State governments accordingly started to implement regulations for micromobility devices. While most state governments and other countries specify the speed limit, age, and licensing requirements, individual cities may have stricter regulations regarding where the devices may be operated. Washington D.C. implemented one of the strictest caps for micromobility speed limits in the county with all e-scooters restricted to 10 mph or below (Insurance Institute for Highway Safety, 2023). Alternatively, some municipalities and states have chosen to temporarily ban these devices until regulations are fully in place to protect their citizens (Wood et al., 2019).

E-scooter operators in many states are restricted to bicycle lanes, sidewalks, or roadways. This can cause problems when determining who has right-of-way at an intersection as well as whether electric micromobility devices should be allowed on the same paths as pedestrians. Cities have started to implement regulations that only allow micromobility devices on bicycle lanes or the street where bicycle lanes are not available (City of Raleigh, 2024). Some cities have found from their pilot studies that due to the dockless design of many micromobility devices, users may leave the devices in undesignated areas when they are finished renting them. This can lead to the devices being parked in the middle of a sidewalk, further impeding pedestrian traffic, or on a curb precipitating the risk of falling into or being hit by a moving vehicle. See an example of the unusual places these e-scooters can end up in Figure 3. Directives made by some cities include maps or advice directing where to leave a micromobility device when no longer in use.

Figure 3

E-scooters found in a tree on North Carolina State University's Campus

Federal Motor Vehicle Safety Standard (FMVSS) #500 requires that LSVs be equipped with a parking brake, i.e. “a mechanism designed to prevent the movement of a stationary motor vehicle” but does not mention a mechanism for stopping LSVs while in motion, nor does any other FMVSS applicable to LSVs (Seluga & Ojalvo, 2006). Additionally, the most recent ANSI (American National Standards Institute) safety standards pertaining to the safe operation of golf carts and ATVs, *ANSI/OPEI Z130.1-2020: Golf Cars - Safety and Performance Specifications* and *ANSI/SVIA 1-2023: Four Wheel All-Terrain Vehicles*, do not include any requirements for seatbelt use. This may be attributed to golfers frequently entering and exiting their carts when on golf courses and thus viewing seatbelts as a hindrance rather than a safety precaution. Likewise, ATV riders prefer quick mounting and dismounting of the vehicle and often freely shift their body weight while in operation, particularly around sharp turns (Technology Associates, 2018). Commonly, “such vehicles only provide braking for their rear wheels, which can lead to a driver losing control during travel on typical steep downgrades. Besides reducing braking efficiency, it has been demonstrated that installing brakes on only the rear wheels can lead to directional instability (fishtailing) and rollover when the rear wheels are braked until skidding occurs” (Seluga & Ojalvo, 2006). There are currently gated communities, such as for golf courses and beach and mountain environments, that restrict vehicular travel other than by various low speed vehicles. Bald Head Island in North Carolina is a community only accessible by ferry or private yacht, and passenger cars are banned in favor of golf carts, bicycles, and trams. Visitors must adhere to the island’s rules and regulations specific to golf cart licensing, alcohol consumption and speed limits (Bald Head Association, 2024). In Wrightsville Beach, North Carolina, the universal “no symbol” is used to prohibit bicycle traffic on sidewalks, as shown in Figure 4 below.

Figure 4

Universal No Symbol Prohibiting Bicyle Traffic

Golf Cart and ATV Injuries and Fatalities

Both LSVs and micromobility devices lack the mass of small cars and trucks, and consequently cannot provide the same level of protection from side, front, rear end collisions, or rollovers. The number of injuries sustained while operating these vehicles and devices has been growing over the past several years, as demonstrated by a study analyzing patients admitted to U.S. emergency departments for golf cart related injuries from 2007 to 2017. Using data from the National Electronic Injury Surveillance System (NEISS), researchers found that:

- An estimated 156,040 patients were treated in U.S. emergency departments for golf cart-related injuries
- The average rate of traumatic brain injuries (TBIs, a disruption of normal brain functions, usually caused by a bump, blow, jolt, or penetrating injury to the head and are classified as mild, mild repetitive, or severe) in children (1.62 per 100,000 children) was more than three times that of TBIs in adults (0.52 per 100,000 adults) and nearly twice that of TBIs in seniors (1.11 per 100,000 seniors)
- The rate of injuries in seniors increased significantly by 67.6% from 4.81 per 100,000 seniors in 2007 to 8.06 per 100,000 seniors in 2017" (Horvath et al., 2020).

In 2022 alone, there were 498 golf cart related injuries accounted for in the NEISS database. The most common golf cart related injury, both fatal and nonfatal, is falling off the golf cart (i.e. passenger ejection) which occurs during a sharp turn when the centrifugal force causes a passenger to shift in the opposite direction the vehicle is turning (Technology Associates, 2018). The risk of passenger ejection is greatly reduced for occupants properly wearing a lap belt when a golf cart or utility vehicle takes a sharp and/or fast turn. ATV statistics from NEISS revealed:

- 1,591 fatalities associated with four-wheeled ATVs occurred over a three year span from 2016-2018
- 352,100 emergency department-treated injuries were reported over a five year span from 2016-2020
- Fractures are the most common (30%) injury diagnosis and the head/neck is the most commonly (also 30%) affected body part

According to the Insurance Institute for Highway Safety (IIHS), the rate of fatal injuries for ATV riders aged 40 and older in the U.S. has increased from 9% in 1982 to 45% in 2021. The injury rate per 100,000 population for the 12-15 age group has seen the most significant increase from 71.7% ATV riders being affected in 2018 to 95.8% in 2020 (Topping, 2021). This increase in injuries can be attributed to individuals, mainly teenagers, who began ATV riding as a recreational activity that could keep them outdoors while still isolated from others during the COVID-19 pandemic. Some motorsports retailers that closed in 2020 due to COVID-19 restrictions were later deemed essential businesses and reopened since they also provided ATV equipment for farmers and firefighters (Shoup, 2020). Farmers use ATVs for agriculture related tasks such as pulling trailers/heavy loads, gathering livestock, applying pesticides and fertilizers,

and maintaining fences. In fact, OSHA (Occupational Safety and Health Administration) previously reported that of the 321 ATV fatalities that occurred between 2003 and 2011, 60% were agriculture related (U.S. Department of Labor, 2015). Firefighters use ATVs for emergency response extraction, wildfire management, and transporting EMS personnel.

E-Scooter, E-Bike and Hoverboard Injuries and Fatalities

Micromobility devices allow people to take shorter trips without using a car or other vehicle, reduce traffic congestions, and contribute to lower greenhouse gas emissions (City of Raleigh, 2024). Schellong et al. noted in 2019 that users were rarely observed using any kind of protective equipment when riding and PPE was not provided when renting. Table 2 shows data extracted from BLS for the number of fatalities associated with the use of select micromobility devices including e-scooters, e-bikes and hoverboards in the U.S. over a six-year span from 2017 to 2022. “From 2017 to 2021, injuries spiked 127% to 77,200 for micromobility devices, and the number of deaths rose from 5 to 48. E-scooters had the highest percentage increase in injuries and accounted for 68 deaths in the same time period. Consumer-owned e-scooters accounted for most ER visits (56%), with incidents involving rental e-scooter at 44%” (Tark, 2022). The differentiation in Table 2 between e-scooters owned by a private individual is the non-parenthetical value, and those owned by rental companies is the parenthetical value.

Table 2

Number of Fatalities Associated with the Use of Micromobiltiy Devices in the U.S., 2017 - 2022

Year	All Micromobility	E-Scooter (Dockless/Rental)	Hoverboard	E-Bike
2017	5	1 (0)	4	0
2018	11	5 (2)	0	6
2019	31	25 (7)	0	6
2020	34	14 (2)	2	18
2021	76	36 (4)	8	32
2022	76	30 (3)	4	42
Total	**233**	**111 (18)**	**18**	**104**

In 2022, the Behavioral Traffic Safety Cooperative Research Program published the results of a multiyear study focused on e-scooter safety. The study found that “head and upper extremity injuries, especially fractures, were prevalent among e-scooter injuries, although the frequency varied” and that “motor vehicles such as cars and trucks are involved in more than

80% of e-scooter and bicycle accidents with rider fatalities" (Sandt et al., 2022; Santacreu et al., 2020). The prevalence of these injuries sustained by users of LSVs and micromobility devices emphasizes the need for more safety features. Enforcing the use of head protection by riders while operating micromobility devices is of particular importance. "In Washington, DC, a study comparing injuries to riders of personally owned bicycles with riders of shared e-scooters found that injured e-scooter riders wore helmets significantly less often than injured bicyclists (<2% of e-scooter riders vs. 66% of bicyclists)... e-scooter riders were almost three times more likely than bicyclists to experience a concussion and lose consciousness" (Sandt et al., 2022; Cicchino et al., 2020).

Those who are employed in food and cargo delivery may face pressure to complete their deliveries as quickly as possible, sacrificing their physical and mental well-being in the process. "In China, the time pressure includes fines for late deliveries while in Britain, riders reported that late deliveries led to them being allocated less work in the following days. While the British riders reported physical fatigue from long hours riding human-powered bicycles, the Chinese riders of e-bikes (which do not require pedaling), experience mental fatigue from planning optimal routes to deliver several orders to different customers in the one trip" (Ovideo-Trespalacios et al., 2022).

Improper operation by cyclists, due to inexperience or negligence, is also a contributing factor to rising injury rates, particularly in Shantou City, China. "Many EB (electric bike) cyclists lack road-traffic safety knowledge and have weak awareness of laws and traffic-safety regulations… The incidence of dangerous behaviors such as drunk cycling, retrograde cycling (riding opposite to the usual and expected traffic flow), violating traffic lights and using mobile phones while riding among people with ERTIs (electric bicycle road-traffic injuries) was higher than that of non-ERTIs" (Zhong et al., 2022). Since there is no required certification or training needed in order to operate a micromobility device, many users may not be fully aware of the associated risks. Utility vehicle drivers normally undergo safety orientation as part of their job duties and their behaviors may be addressed for disciplinary action if the unsafe practices are on company property. Wumbus Corporation is a company centered in Irvine, California that offers a variety of corporate training programs and OSHA compliance workplace safety training videos, including *The Safe Operation of Utility Carts*. They provide that "cart operators must be informed about the site procedures, familiar with the facility layout, and well versed with the operation of each vehicle in use by the facility" (Wumbus Corporation, 2003).

Firms that use LSVs or micromobility devices, should ensure that they have programs in place for training employees on proper use and appropriate maintenance. Sources to examine for this information should include the equipment vendor from which the devices were purchased, and any trade associations specific to that equipment in which the purchaser may be a member. In addition, firms that use devices for work or reasonably suspect they are used during off work

hours, should include safety programs or make these available for review and encourage their use. ANSI/ASSP Standards Z490.1 and Z490.2 should be used for guidance in management, training programs/course development, training delivery, training evaluation, and documentation and records review for safety training.

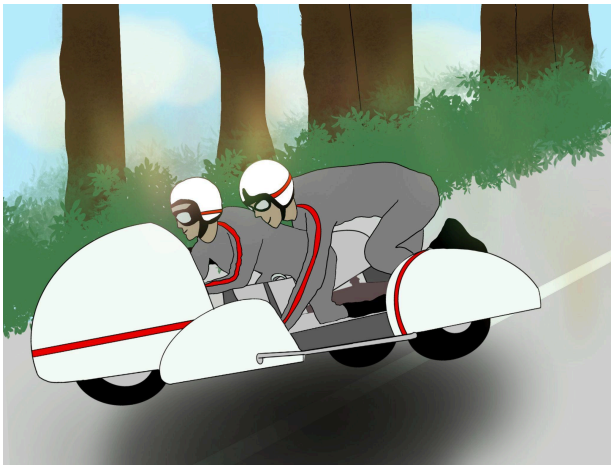
Hoverboards rose to prominence in the U.S. around 2014 after inventor Shane Chen designed but did not patent the device, causing several Chinese factories to put them into production (Shepard, 2018). The USDOT describes these devices as "balance boards, gravity boards, or self-balancing devices that contain lithium batteries" (U.S. Department of Transportation, 2015). Users control the device by slightly leaning forward or backward and adjusting pressure between the feet. By 2015, popularity of the hoverboard skyrocketed as people of all ages used it for recreational activities and transportation over short distances. During that same year, users quickly realized how unsafe these devices can be, yet there was no established standard or regulation for manufacturers to follow. This led to the U.S. Consumer Product Safety Commission (CPSC) publishing UL 2272 *Standard for Safety of Electrical Systems for Personal e-Mobility Devices* in 2016 which outlines requirements for device construction as well as electrical, mechanical and environmental testing procedures. It has since been adopted by the American National Standards Institute (ANSI) and the Standards Council of Canada (SCC). CPSC staff noted that from December 2015 through February 2016, fires directly related to hoverboards resulted in more than $2 million (USD) in property damage (Underwriters Laboratories, 2017). Subsequently, several major airlines have banned hoverboards on flights and universities have banned them on campuses. For these reasons, hoverboards have not been seen as a safe method of micromobility transportation. CPSC provided in 2016 that any hoverboards still being used must be compliant with UL 2272 or taken out of service.

Select Racing Organizations

The Isle of Man TT (Time Trial or Tourist Trophy) is a motorcycle race which runs for two weeks at the end of May on the Isle of Man island, situated in the Irish Sea between England and Ireland. The race covers 226 miles with 6 laps, each 37.73 miles, and over 200 turns on public roads that are closed only 30 minutes prior to the race. Participants undergo one week of practice and qualifying to race and one week of racing. The New York Times reported that during the 2016 race, more than 42,000 people from over 40 countries visited the island and generated around $40 million for the local economy. One bar along the course, The Creg-Ny-Baa, earns about a third of its yearly business during the weeks that the race occurs (Keh, 2017). Side cars, as illustrated in Figure 5, were used from 1923 to 1926 and then again from 1954 to the present day (Isle of Man Government, 2019). In recent years, the number of racers has been restricted to 100 solo riders and 30 sidecar teams.

Figure 5

Reenactment of motorcycle and sidecar in TT race



The second person in the sidecar serves as a ballast by shifting their weight to the side to oppose overturning forces, and does not use a seat belt or harness as that would preclude the use of their weight when kneeling or standing. Even with full protection, including padded bodysuits, gloves, and helmets, participants in this race are at risk for serious injury with some course speeds exceeding 200 mph. To date, 1982 has been the only year where an Isle of Man TT race was completed without any fatalities since resuming after World War II in 1947 (Watterson, 2022). There have been 269 fatalities on the Snaefell Mountain Course since 1911 with 6 of those deaths occurring in 2022, making it the deadliest year for the TT race. Other persons riding in a motorcycle sidecar, not racing, should be provided with and using a seat belt.

In 2022, London hosted the first eSkootr Championship (eSC), a competitive electric scooter racing series where participants race using the S1-X eSkootr specifically designed for this type of race. Thirty professional athletes, male and female, from around the world and from a range of sports such as skiing, surfing, BMX racing, and stunt driving, competed in the inaugural year. Organizers of the event stated “eSC promotes the use of micromobility transportation in urban areas for a smarter, cleaner tomorrow” (eSkootr Championship, 2023). In December 2023 the first Dubai Electric Scooter Cup took place in the D3 Dubai Design District. Alex Wurz, president of the Federation for Micromobility and Sport, stated “The sport will also act as an accelerator for new technologies, making the entire micro-mobility sector safer, more socially acceptable and regulated” (Van Zyl, 2024). Sixteen male and female riders competed using the RS-Zero DXB e-scooter, a device specially designed for use in this cup. Dubai has contributed significantly to the mobility sector and in the future hopes to further technological developments for electric vehicles, particularly in regards to public transport and the working class (Muzoriwa, 2023; Maksoud et al., 2023).

Societal and Infrastructure Advancements

Many cities only have designated lanes for bicycles alongside road traffic, meaning users of micromobility devices are restricted to sidewalks where pedestrian traffic is an obstacle. “When LSVs share a right-of-way with higher-speed passenger vehicles and trucks, it imposes a great risk to the LSV’s operator and passengers because of the speed differential and the dissimilar construction of the two types of vehicles” (Hunter-Zaworski, 2012). This is of particular concern to colleges across the U.S., which were pivotal in the adoption of micromobility devices as students used them for getting to classes and working on-campus jobs, such as providing campus tours, transporting student athletes and equipment, and grounds maintenance. In recent years, several colleges and universities have announced bans for electric vehicles on their campuses, citing fire safety risks and pedestrian collisions as causes for concern. Some students understand the reasoning behind this ban, but they also believe the vehicles could still be safely used with implementation of fines for students who do not adhere to safety policies and dedicated travel lanes (Abdulahi, 2022).

Many cities in the United States and international countries put either a proactive or retroactive ban on micromobility devices in the late 2010s to ensure that governments and safety organizations could develop proper regulations before widespread use by their citizens (Wood et al., 2019). Russia conducted a 2022 pilot study to observe these micromobility devices for insight on needed regulations and in March of 2023, the country lifted the ban for micromobility devices (Higher School of Economics, 2023). This is similar to cities’ regulations across the U.S. Pilot studies were introduced to see the potential impacts, which were then used to form proper regulations (Wood et al., 2019). While the only two U.S. cities to put a proactive ban into place were San Mateo and Santa Clara in California, a list of some of the U.S. cities that have implemented retroactive bans includes:

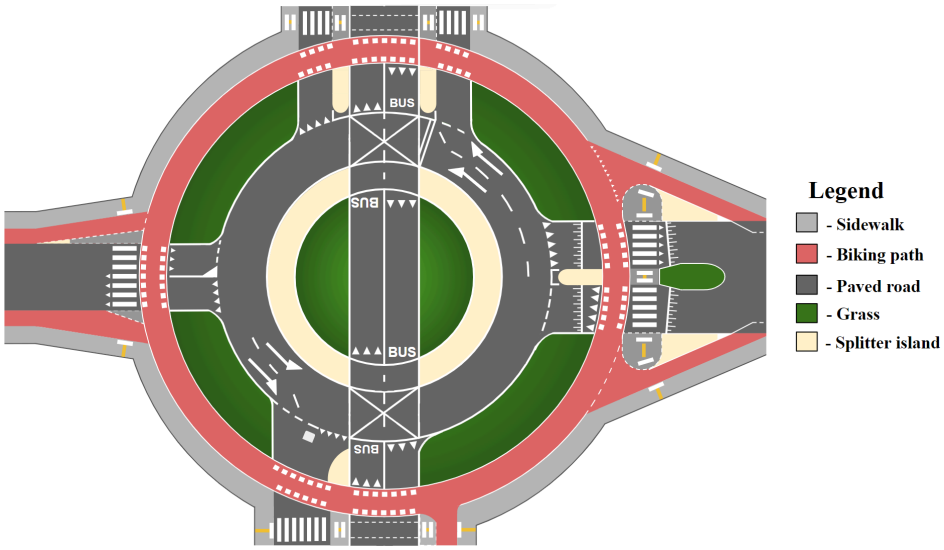
- Athens, GA
- Birmingham, AL
- Columbia, SC
- Isla Vista, CA
- Lafayette, LA
- Miami Beach, FL
- Seattle, WA
- Winston-Salem, NC
- Tucson, AZ
- Beverly Hills, CA
- Santa Barbara, CA
- Frederick, MD
- Asheville, NC
- South Padre Island, TX

Among all European countries, the Netherlands has the highest population of active bike and e-bike riders, along with the advanced infrastructure to support them. A rise in traffic accidents in the 1970s, particularly those involving children, sparked the transition from favoring automobile traffic to favoring bikes and other man-powered traffic instead (Goeverden, 2015; Thomas, 2023). Thus, the Dutch government invested heavily in a network of bike lanes and discouraged the use of automobiles via traffic calming, a method that aims to make traveling by

car more of a nuisance than a convenience. There is now a variety of shared spaces in the Netherlands and Denmark where pedestrians, bicyclists and electric device operators can safely use the same infrastructure, as shown in Figure 5. Access roads in the Netherlands and Denmark, which are located in residential areas, have maximum 30 kph (18.6 mph) speed limits and motorists drive on the right side, forming a counterclockwise motion within the roundabout.

Figure 5

Example of Roundabout in Aalsmeer, Netherlands



In the U.S., existing roundabout designs favor automobile traffic and do not always have protected paths for LSVs or micromobility devices. NYC has designated bike and e-bike lanes painted in green that are located between pedestrian sidewalks and vehicular traffic, such as shown in Figure 6 below, at the intersection of 1 Av (1st Avenue) and E 90 St (East 90th Street).

Figure 5

Designated Bike Lane in New York City (Maps Data: © 2024 Google)

Vehicle charging stations are a major infrastructure need. California is one of the leading states in regards to electric vehicle charging infrastructure. The West Coast Green Highway, a network of electric vehicle fast charging stations that primarily runs along Interstate 5 and Highway 101, begins in San Diego, CA and continues through Oregon and Washington before ending near Vancouver, BC. Drivers of electric cars can travel longer distances and reach less developed areas using this highway. In 2022, Oregon began adding e-bike charging stations along their portion of the highway network and plans to add more as they study micromobility trends over the coming years (Washington State Department of Transportation, 2014; Baumhardt, 2022).

Andrew Fox is the former CEO and co-founder of Charge Enterprises, Inc., a micromobility company based in New York that builds storage and charging stations for e-bikes and e-scooters. Fox previously noted that "Most e-scooter operators rely on a network of contractors to collect scooters each night, charge them in their homes and then redistribute around the city – a clever, yet inefficient and potentially hazardous practice… which mandates significant travel time for juicers (charging employees), resulting in operational downtime and profit losses for e-scooter operators. Worse still, juicers face fire hazards when connecting multiple e-scooters to one residential circuit" (Business Wire, 2020). Infrastructure investment for designated charging stations should reduce the risk of pedestrian traffic being impeded by poorly docked devices while also increasing safety for workers tasked with the collection and distribution of micromobility devices across cities.

Implementation of safety tools for electric powered vehicles

Standard automobiles come with safety features including headlights, anti-lock brakes, horns, airbags, backup cameras, traction control and safety belts (Heaps, 2023). The invention of the safety belt is attributed to former Swedish aviation engineer Nils Bohlin, who worked with Volvo to patent and sell the first three-point seatbelt in the Volvo Amazon and PV544 car models in August of 1959. Volvo allowed other companies to use the patented design, leading to U.S. federal law mandating seat belts in 1968 (Volvo Car Corporation, 2009). However, micromobility devices do not have as many safety tools built in and users must purchase their own additional protection. Newer models of the Lime scooter, an e-scooter launched by the transportation company Lime in 2018, are only equipped with dual drum front and rear brakes. Some micromobility device models are equipped with bells and LED lights, although it is not uniform across different companies. Postmates is currently the only delivery app that requires micromobility users to wear a helmet when dropping off or picking up an order (Fiscal Flamingo, 2019). New technology is being developed for e-scooters which "detects unsafe behaviours like sidewalk riding, wrong-way riding, aggressive swerving and repeated hard braking, that is immediately corrected by slowing or safely stopping the scooter in real time" (Cities Today, 2022). Individuals and organizations seeking additional safety features can purchase an audible warning device with different tones for their device, such as a horn, that alerts others of their presence on a roadway or designated path.

Electric golf cart manufacturers have begun to implement advanced lighting systems which may include programmable LEDs, turn signals, and brake lights to improve visibility and reduce accident risks. Many newer electric golf carts also come equipped with seat belts along with collision detection and automatic braking systems (Saera Electric Auto, 2023). Depending on the model, some UTVs and ATVs are designed with roll cages designed to protect occupants in the event of a rollover or collision. For younger ATV riders there are three different categories that travel at slower speeds and are designed to accommodate smaller hands and feet. Parents can invest in an exhaust port restrictor to limit engine power and a kill switch lanyard that turns off the engine by the pulling of a cord, as well as a neon safety flag that attaches to the antenna for visibility. The best way to ensure UTV and ATV safety is to wear a helmet, goggles, long sleeves, long pants, over-the-ankle boots, and gloves. (ATV Safety Institute, 2024; U.S. Consumer Product Safety Commission, n.d.).

Conclusion and Recommendations

Thousands of injuries occur each year due to operation of LSVs and micromobility devices but reporting of accurate injury data needs improvement. The U.S. may benefit from a federal standardized system for assessing injuries and fatalities sustained from low speed vehicles and micromobility devices. CPSC staff have faced problems especially when distinguishing between occupational and non-occupational use when classifying reported ATV fatalities. Data for other micromobility devices have not been so affected by occupational/non-occupational classifications. Hospitals across the U.S. cannot track micromobility related injuries where individuals did not seek medical attention (Topping, 2021; Cherry et al., 2021). Safety may be greatly improved with the development of designated lanes for alternative modes of transportation other than bicycles. Charging stations that eliminate transportation of e-bikes and e-scooters in addition to electric cars should reduce several occupational risks, including manual lifting and fire hazards.

Both international governments and the U.S. government as well as regulatory organizations continue to develop regulations and standards pertaining to the safety of micromobility devices. Insurance companies may also aid in choosing the most appropriate low speed vehicle or micromobility device depending on an individual's transportation needs and local/state regulations. Even if not required, operators of golf carts, UTVs, ATVs, e-scooters, and e-bikes may purchase safety add-ons such as handlebar mounted horns, turn signal lights, rear view mirrors attached to the helmet, and reflectors to alert others of their presence and avoid sustaining injuries from collisions. To ensure that a golf cart and its operator are street-legal, seatbelts, a horn and side mirrors can be purchased (INOKIM, 2023; Mitran et al., 2020). Individuals who use these vehicles and devices for occupational purposes, such as cargo/food delivery, warehouse maintenance or agriculture, should be trained to follow company policies and industry regulations for safe operation. The purchaser and user of any of these devices

should use all the training materials provided by that vendor as part of their training and periodic retraining for the user. In addition, users of these devices should stay abreast of any standards that may become available for that device. Many courier businesses encourage the use of helmets via safety tips on their websites and campaigns partnering with the Governors Highway Safety Association (Boman, 2019). In addition to helmets, the CDC also recommends users attach lights to their bikes and wear high visibility or light-up vests for better protection, as demonstrated in Figure 6 (Centers for Disease Control and Prevention, 2022). Hoverboards, a micromobility device, should only be used recreationally; parents should monitor closely when they are in use by children due to associated fire risks, especially with lithium-ion batteries. Children and those under age 18 are most at risk for developing a severe injury, such as a TBI, when operating a low speed vehicle or micromobility device. This population poses a greater occupational risk of injury when using micromobility devices.

Figure 6

Bicycle Safety Add-ons

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